MISCELLANEOUS STUDIES ON THE CROWN RUST OF OATS [1]

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During a somewhat extensive study of the infection capabilities of crown rust of oats, *Puccinia coronata* Cda. (1), the following data were collected.

I

McAlpine (2) ventures the opinion that crown rust of oats was probably introduced into Australia by means of seed. He does not state whether he thinks the rust was carried within or upon the seed in the form of mycelium or of urediniospores.

As far as surface-borne urediniospores are concerned, it seems questionable whether under ordinary conditions urediniospores would remain viable upon the seed surface long enough to be transported to any great distance and still be able, after relatively long periods of time and probably under adverse environment, to infect the developing seedlings. In an attempt to throw some light upon this question the following experiment was devised:

Twenty oat seeds of a variety known to be susceptible to crown rust (Victory, Minn. 514) were moistened in water and heavily smeared with fresh viable urediniospores. Five seeds were then planted about one half inch deep in each of four four-inch pots of a uniform soil mixture. These pots were placed in a ventilated cage in order to protect the developing seedlings from chance infection from air-borne spores.

After the seedlings had been allowed to grow for ten days, a sufficient period to show evidence of infection, it was found that none of the twenty seedlings became infected. The temperature within the cage was previously determined to be an optimum one, since artificial inoculations of seedling leaves of the same variety in the same environment resulted in normal infection, and moisture was present in sufficient amounts to cause guttation from the seedling leaves.

These results, though the experimental work was not extensive, would seem to indicate that in the case of *Puccinia coronata* Cda., urediniospores borne upon the surface of the seed do not commonly offer a favorable means of spreading the rust to the seedling plants developed from these seeds.

[1] Investigations carried on while the author was a graduate student at the University of Minnesota, 1916–1918.

II

In the field, the soil beneath cereals heavily rusted with *P. graminis* Pers. is often found literally covered with fallen urediniospores. The idea has been conceived that seedlings penetrating such soil might become infected and the rust be aided in its spread in this way. Greenhouse experiments have proven this possible, it is reported, with *P. graminis* Pers. In order to determine if such infection is possible in the case of *P. coronata* Cda., the following experiment was devised:

After soaking in water for twenty-four hours, six oat seeds were planted about one half inch deep in each of four four-inch pots of a uniform soil mixture. The surface soil was then heavily dusted with fresh viable urediniospores. These pots were then placed in a ventilated cage to avoid possible chance infection of the seedlings by air-borne spores. Watering was avoided in order to prevent germination of the spores before the seedlings should come in contact with them. After ten days' time none of the twenty-two seedlings that developed showed any signs of infection, though guttation occurred from the seedling leaves, affording optimum conditions for spore germination.

These results indicate at least that seedling infection caused by emergence through soil densely covered with viable urediniospores does not occur readily. This condition may possibly be due to the fact that the sheath which surrounds the emerging seedling is not supplied with stomata and therefore affords no opportunity for the entrance of the germ tubes.

III

The possibility of urediniospore-producing mycelium overwintering in the host plant and producing a new crop of urediniospores in the spring, together with the overwintering of urediniospores in the field, was considered.

Christman (3) found, under Wisconsin conditions, viable urediniospores at any time during the winter with a three-months' period during which the temperature hovered about the freezing point. Urediniospores from oats, developed upon protected plants during the winter, germinated as late as January 26. Indications were that the mycelium would be as resistant as the host within which it grew. Old spores remained viable for some time, though new crops of spores from overwintered mycelium seemed to be the more important mode of spring infection.

Reed and Holmes (4) found viable urediniospores on oats throughout the year under Virginia conditions. They conclude that the crown rust on oats has an enduring mycelium capable of producing a new crop of spores during much of the winter, and although spore production ceases during midwinter, the mycelium, upon the advent of warm weather, is capable of producing new crops of viable spores.

The urediniospore-germination studies that the writer has performed would seem to indicate that under Minnesota conditions urediniospores

cannot withstand the extremely low temperatures of winter. In the field, even before winter had set in, all urediniospores had disappeared and only the teliospores were in evidence. Two pots of heavily rusted oat plants were allowed to remain outside during the winter. The plants were winter-killed and when removed to the greenhouse in early April did not revive. The urediniospore-producing mycelium, if still alive, which one would naturally doubt, produced no new crop of spores.

From this more or less limited observational evidence, then, it seems improbable that under Minnesota conditions a perennial mycelium exists which is capable of producing a new crop of urediniospores the following spring after overwintering on the infected oat host, though Bolley and Pritchard (5) consider it in general quite possible, even though no experimental data are offered to substantiate the opinion. It seems equally improbable that the urediniospores themselves can overwinter and cause infection the following spring. Just what possibility there is of the existence of a perennial mycelium or of the overwintering of the urediniospores among the wild grasses, has not been determined.

IV

Mains (6), working with *Puccinia coronata* Cda., has shown that low temperatures, lack of moisture in the moist chamber, and the absence of light retard the development of the leaf rust of oats.

These same observations have been made in the present work, though only one definite experiment was performed and that to determine the effect of light upon the degree of infection and the rate of pustule formation.

Four pots of oats of the same seed lot, grown under the same conditions, were inoculated on the same date with inoculum from the same source. Two pots were placed in a pan of water and covered with a glass bell jar; the other two pots were given similar moisture and temperature conditions though covered by a glass-topped metal moist chamber from which light was excluded.

All four pots were removed from the moist chambers after forty-eight hours but retained for two days more under the light and dark covers. At the end of this period the plants in the dark had become spindly and distinctly yellowed. Flecks appeared on all the seedlings in all the pots at about the same time. Pustules ruptured within ten days upon the plants kept in the light and within twelve days on the plants kept in the dark. Infection, one hundred percent in each case, appeared normal on all the seedlings, though not so heavy on the plants grown in the dark. The plants that had been kept in the dark, after several days' exposure to the light showed nearly normal growth, though the effect of etiolation was evidenced by dead areas at the tips of the leaf blades.

Twenty-eight days after inoculation pigment appeared on one of the plants that had been exposed to the light, while twenty-six days after

inoculation a profuse production of teliospores was noted on every plant in one of the pots that had been kept in the dark. (See figure 1, Plate XXIV.)

V

The appearance of a purple pigment surrounding infected areas of the oat leaves inoculated with crown rust is not uncommon. The variety of the host plant, its age before inoculation, the length of time of infection, the history of the inoculum, its method of application, and all other externally visible environmental factors seem to have no direct correlation with this phenomenon of pigment formation.

Wheldale (7), regarding this anthocyanin pigment formation in plants attacked by fungi, says:

> It is frequently found that the pathological conditions called forth by the attacks of fungi are accompanied by abnormal development of anthocyanin. In leaves of Tussilago, for instance, infected by Puccinia, a circular band of anthocyanin often appears surrounding the aecidium spots. . . . Injury to the living tissues of the conducting system of the veins, midrib or petiole of the leaf, or of corresponding tissues in the stem, leads to an accumulation of synthetic products in the leaves. . . . It seems likely also that parasitic growths may interfere with the progress of the translocation current through the small veins of the leaf, thereby causing congested areas to arise in which the sugar contents are above normal. But it is conceivable that the pathological condition resultant on fungal attacks may be the direct cause, in some way, of pigment formation.

In view of this interpretation and of the relatively general occurrence of this anthocyanin pigmentation during the course of the studies recorded in this paper, the assumption seems justified that pigment formation, as a phenomenon connected with the infection of oats by *P. coronata* Cda., is not a sign of resistance on the part of the host to the attacks of the rust parasite.

VI

Parker (8), speaking of early production of telia on oat seedlings, says:

> It is certain that in the hundreds of seedlings described as very susceptible in the present experiments telia were not produced on a single one following a normal and abundant production of uredinia.

In the investigations reported in this paper, this was not the case. Although certain oat varieties showing resistance to attacks of the crown rust did produce telia, other very susceptible varieties also produced telia freely and in great abundance. Super-susceptibility on the part of the host may bring about the formation of telia due to conditions as explained by Wheldale, although resistant hosts may react in some way so as to be unfavorable to continued urediniospore production on the part of the fungus, and thus hasten the completion of its life cycle and the early production of telia.

Parker has used this phenomenon of teliospore production, in certain cases, as a basis for the classification of resistant varieties. In view of results recorded here, such a basis for the classification of resistance would seem unreliable. Ligowa oats were listed as susceptible, and yet, during the

course of these experiments, Ligowa oats, although heavily infected, produced pigment and telia both when growing under normal conditions and when subjected to adverse environmental circumstances. (See figure 1, Plate XXIV.) *Avena sterilis* L. is considered by Parker as for the most part susceptible. In the experiments here reported it produced pigment, telia, and extensive hypersensitive areas. Figure 2, Plate XXIV, shows leaves of *Avena sterilis* L. infected by *Puccinia coronata* Cda. The strain[2] of rust from Saint Paul, Minnesota, indicated by "S," caused a very light infection, the appearance of small scattered uredinia and large hypersensitive areas, and the early production of telia. The strain of rust from Tallulah, Louisiana, indicated by "T," caused heavy, normal infection without any evidence of pigment or telia formation. Swedish Select oats Parker considered susceptible, and yet in these experiments Swedish Select oats from Virginia produced telia in abundance. Appler oats Parker considered resistant. Figure 3, Plate XXIV, shows Appler oats from Alabama infected with *P. coronata* Cda. "T" shows normal infection with the strain of rust from Tallulah, Louisiana; "S" shows a heavy production of telia and extensive dead areas by the Saint Paul, Minnesota, strain. Parker considered Burt oats susceptible. In the present experiments Burt oats from Alabama showed a similar condition to that described for Appler.

Therefore, though the production of telia when associated with other phenomena indicating resistance may be additional evidence to justify the classification of oat varieties as resistant, certainly results obtained in the present work seem to show that this phenomenon of telia formation on oat seedlings is variable and largely dependent upon environmental factors and possibly also upon the strain of rust employed, to such an extent at least as to make telia formation a rather unreliable basis for the determination of true resistance.

Summary

1. Urediniospores borne on the surface of oat seeds do not offer a ready means of infecting seedlings developed from these seeds.

2. Seedlings of oats emerging through soil heavily covered with viable urediniospores are not readily infected.

3. Under Minnesota conditions, a perennial mycelium, capable of producing a new crop of urediniospores after overwintering, does not exist. What the situation is in the case of wild grasses has not been determined.

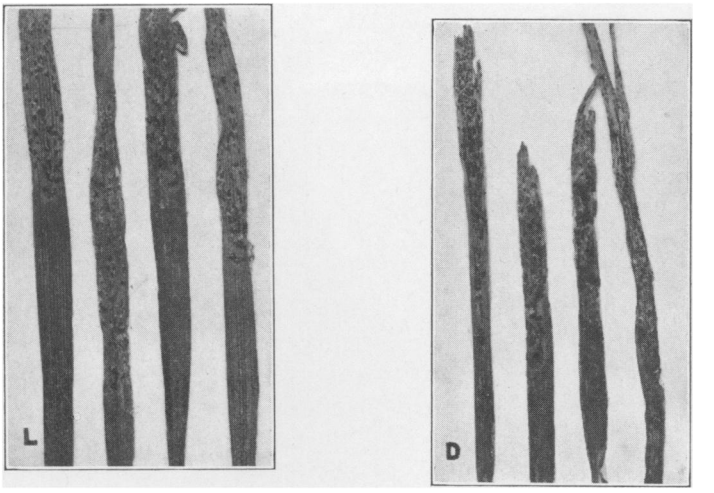
4. Urediniospores do not remain viable over winter on oats, under Minnesota conditions, nor does continued production take place. What the situation is in regard to wild grasses has not been determined.

5. Environmental factors influence the development of the rust on oats as well as the rate of pustule formation.

6. Etiolation brings about the early formation of telia on oat seedlings.

7. Anthocyanin pigment formation surrounding uredinia on infected

[2] The term "strain" is used to indicate merely a locality collection.



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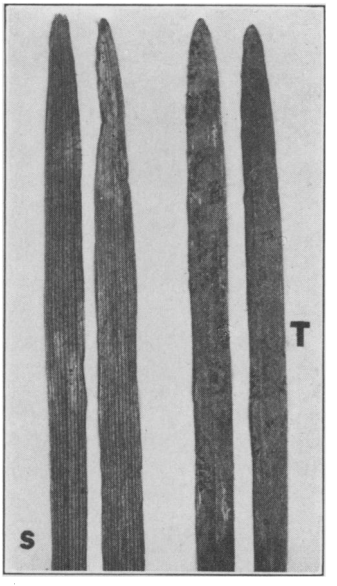

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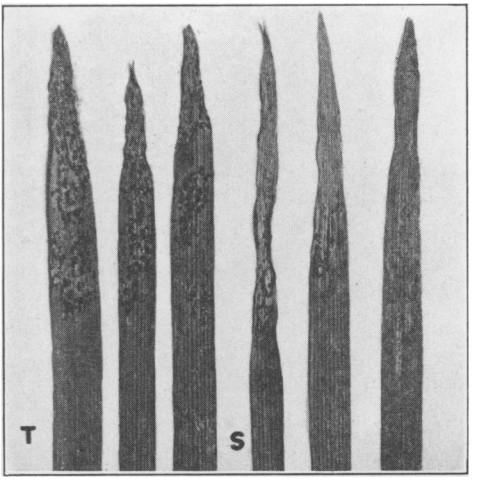

3

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oat leaves is a common phenomenon though not correlated with resistance or susceptibility.

8. The appearance of telia on seedling oat leaves is not a reliable basis for determining the resistance of oat varieties.

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EXPLANATION OF PLATE XXIV

FIG. 1 (above). At "D" the teliospores formed on etiolated seedling oat leaves are shown; at "L" the normal production of urediniospores on the seedlings kept in the light.

FIG. 2 (below at left). *Avena sterilis* L. infected with *Puccinia coronata* Cda. "S" shows the production of telia and of extensive dead areas by the Saint Paul, Minnesota, strain of rust. "T" shows normal production of urediniospores by the Tallulah, Louisiana, strain.

FIG. 3 (below at right). Oats, Alabama-Appler 617, infected with *P. coronata* Cda.